Diel Larval Fish Drift in a Small Ohio Stream (Honey Creek, Seneca Co., OH)

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Abstract. Knowledge of the timing, distribution, and abundance of newly hatched larval fish is helpful in developing an understanding of stream fish ecology. This study investigated the larval fish community in Honey Creek, a tributary to the Sandusky River in Seneca County, Ohio (April-August 2007; total N = 44). Castostomids were the most abundant family of fish collected in the drift, with percids, cyprinids, centrarchids, and ictalurids also present in the stream. Comparisons were made between time of day (day and night) and larval fish density, stream discharge, and turbidity (total suspended solids mg/L). Stream discharge was significantly higher during the day and no difference between day and night samples was observed for total suspended solid concentrations. However, 96.8% of larval fish (total N = 1,328) were collected during the night (22:00-7:00), thus supporting the majority of literature on diel drifting in larval fish communities. Additionally, high proportions of yolk-sac (0.40) and larvae (0.56) were collected. Because high occurrence of early developmental stages of larval fish and significantly higher night densities of larval fish regardless of stream discharge and turbidity were found, the results support the hypothesis that drifting is an active behavior.

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INTRODUCTION

Drift commonly occurs during early life stages of fish and seasonal peak abundances for each species generally occurs in the first weeks after hatching (Reichard and others 2004). Dynamics of diel larval fish movement may be a response to predation avoidance (Muth and Schmulbach 1984, Copp and Jurajda 1993, Zitek and others 2004). Although a majority of larval fish studies focus on large rivers (Reeves and Gallat 2010), little is known about larval fish drift in small streams (Johnson and McKenna 2007). Additionally, the study of larval fish is important since they are typically more sensitive to pollution than adult fish (Tanner and Moffett 1995, Gauthier and others 2006). Because of the sensitivity of larval fish, they have the potential to be useful bioindicators in natural systems.

Many environmental variables can impact larval fish drift. Temporal factors, such as temperature and time of day, may greatly influence larval drift in freshwater rivers and streams (Snyder 1983). Commonly, night densities of larval fish reported for riverine systems are significantly higher than day densities (Clark and Pearson 1980, Carter and others 1986, Gadomski and Barfoot 1998, White and Harvey 2003). Larval fish can also be displaced by floods, because their ability to withstand downstream displacement increases as they grow (Harvey 1987, Reichard and others 2004). Furthermore, timing of severe discharge events may be important to the survival of larval fish (Bednarski and others 2008). The goal of this study was to investigate the abundance and seasonal succession of drifting larval fish in small streams, and to investigate correlations between larval fish densities and other environmental factors (i.e., turbidity and discharge).

Given the available literature (Floyd and others 1984, Gadomski and Barfoot 1998, Johnson and McKenna 2007), it was hypothesized that larval fish would be present in the spring and summer drift of Honey Creek, a small wooded stream in northwest Ohio, and that their densities would be greater at night. Additionally, we were interested in whether observed drift patterns might be influenced by variation in stream discharge rates or turbidity.

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METHODS

Larval fish collection

Honey Creek is a small stream in Seneca County, Ohio (41° 3' 49.45" N, 83° 10' 30.12" W), and has a predominantly agricultural watershed (Richards and others 2001). The main stem (i.e., lower 50 km) is a fourth order stream and has a primarily wooded riparian zone (Loftus and others 2006). Honey Creek has a drainage area of 464 km^2, and flows into the Sandusky River approximately 6 kilometers downstream from the sampling site (Figure 1).

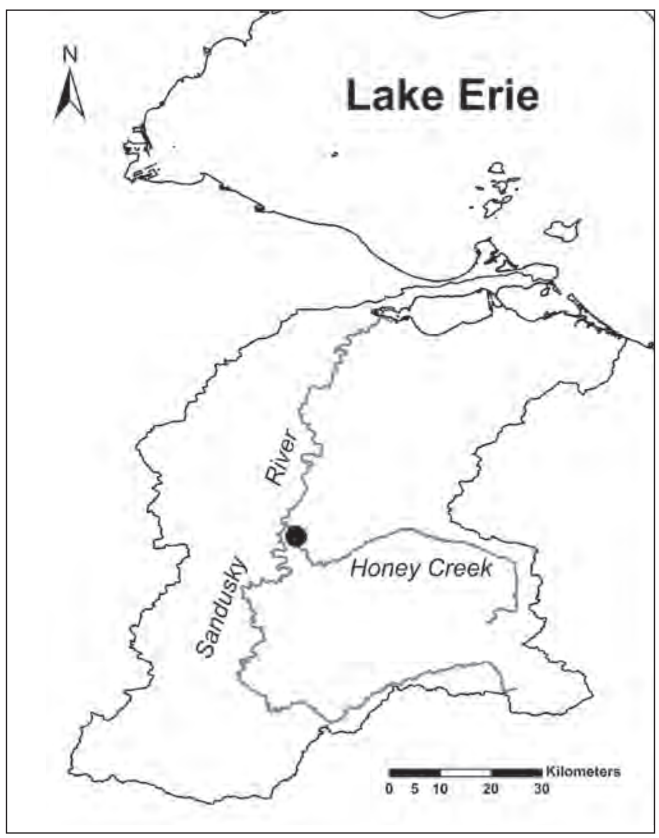

Figure 1. Map of Sandusky River watershed in northwest Ohio. Circle indicates larval fish collection site on Honey Creek, 6 km upstream from the confluence with the Sandusky River.

Samples were collected from April 2, 2007 to August 3, 2007. Larval fish were collected with a 363-micrometer mesh drift net that was anchored to the streambed using rebar (Slack and others 2004). The net was placed in the thalweg and in the center of the water column. Most of the samples were collected under low stream flow conditions, and the net sampled a majority of the water column (Johnson and McKenna 2007). Typically, two replicate samples were taken, each 15 min in duration (Slack and others 2004, Reichard and Jurajda 2007). Under high stream flow conditions, the number of replicates taken was increased to avoid decreased sampling efficiency due to net clogging, but the total time remained 0.5 h. Each sample of larval fish was preserved with formaldehyde and taken to the lab for identification.

Samples were taken frequently in an attempt to avoid missing the pulse of any one particular species of fish. Time of day was chosen haphazardly, alternating between day and night samples as circumstances allowed. Additionally, day and night samples were paired on three dates during the study. Night samples were defined as dusk to dawn (10:00 PM to 7:00 AM; similar to Copp and Jurajda 1993, Kennedy and Vinyard 1997, Reichard and Jurajda 2007). The discharge for each sampling time was recorded from a nearby U.S. Geological Survey gauge station (14 km upstream; Honey Creek, USGS 04100011, Melmore, OH). Additionally, water temperature (°C) and total suspended solids (mg/L; National Center for Water Quality Research) were measured on each sampling date.

The specimens were identified according to Auer (1982). Larval fish were identified as yolk-sac larvae, larvae, or juveniles based on family specific characteristics (i.e., fin ray development, mouth position, and squamation) and measured to the nearest tenth of a millimeter. Although an attempt was made to identify each larva to species, many could only accurately be identified to the family level by identifying the relative position of the anal vent relative to total body length. Because tentative identifications should be left at a higher taxon (Synder 1983), only family level identifications are reported. However, a few species with distinct characteristics could be identified, especially during the late larvae and juvenile stages.

Statistical analysis

Stream flow rates used to determine larval fish densities were calculated using the USGS stream gauge (White and Harvey 2003). A linear regression between stream discharge and stream cross-sectional area was generated with USGS field measurements for Honey Creek from November 2002 to July 2007: stream area (m^2) = 1.1913 x stream discharge (m^3/s) + 4.0927 $R^2 = 0.9557$ Next, the discharge at sampling was divided by the calculated stream area to determine the mean flow rate (m/s). Then the mean flow rate was multiplied by the area of the net (0.116 m^2) to determine the total volume of water sampled. Larval fish densities were reported as individuals collected per 0.5 h divided by the total volume of water sampled (m^3 0.5 h^{-1}). The convention in larval fish research is to present the results in density. Due to the fact that the mean flow rate was used as an index of stream flow, thus assuming the water velocity through a drift net in the thalweg equals the mean water velocity for the stream cross section, larval fish abundances were also reported. Additionally, the method employed that utilizes the calculated mean stream flow is repeatable.

Total suspended solids and stream discharge were analyzed in an analysis of variance (ANOVA) with time of day as the independent variable. In order to achieve normality, suspended solid concentrations (mg/L) were $\log_{10}$ transformed and stream discharge values (m^3/s) were fourth-root transformed (Parravicini and others 2010). Additionally, homoscedasticity of the transformed data was checked with a Brown and Forsythe test (Granier and others 2011).

Larval densities were also compared to time of day (independent variable), but the day samples could not be transformed and normally distributed due to high frequency of zero values. Therefore, a series of nonparametric tests (Wilcoxon/Kruskal Wallis ranked sums tests, a median test, and Van der Waerden normal quantiles test) were used to test for significant differences in larval densities between day and night samples. Probability levels were adjusted for conducting three nonparametric analyses by using a Bonferonni correction, $\alpha = 0.017$ (Reeves and Galat 2010). Though the model selection approach has become increasingly popular in ecological research (Johnson and Omland 2004), this method was not employed in this study. Given the collinearity of the transformed stream discharge and turbidity (linear regression, $p = 0.037$), a singularity in the data was present, violating assumptions of multivariate analyses (McGarigal and others 2000). Additionally, the non-normal distribution of the response variable (larval fish density or abundance) made selection of nonparametric tests more appropriate than a model selection approach. All statistical analyses were conducted using JMP® 8.0.2 (copyright © 2009 SAS Institute Inc).

RESULTS

A total of 1,328 larval fish were collected during the course of the study (44 total samples). Only a small proportion of juveniles were collected (0.04), whereas most of the larval fish collected were yolk-sac larvae (0.40) and larvae (0.56). The low numbers of juveniles collected was likely due to their increased ability to avoid gear. As expected, catostomids and percids were the first families to be present in the drift, followed by cyprinids, centrarchids, and ictalurids as the summer progressed (Table 1). Catostomids were the most abundant family present in the drift, representing 80% of the total larval fish community in Honey Creek.

Table 1

Larval fish abundance and occurrence by family in Honey Creek, 2007.

	Abundance	Proportion of Total	Date Range
Catostomidae	1,058	0.80	4/30 - 6/9
Percidae	135	0.10	4/30 - 6/11
Cyprinidae	106	0.08	5/11 - 8/3
Centrarchidae	16	0.01	5/13 - 8/3
Ictaluridae	13	0.01	6/25 - 8/3

There was no significant difference in concentrations of total suspended solids between the day and night samples (ANOVA; $F_{1,42} = 1.79$, $p = 0.1887$; Figure 2). Stream discharge was significantly higher in the day samples (ANOVA; $F_{1,42} = 5.67$, $p = 0.0219$; Figure 2). However, this was likely due to the fact that the two highest stream discharges measured (5.86 m^3/s and 7.05 m^3/s) both occurred during day samples. Additionally, the majority of samples occurred under base-flow stream discharges. For example, the overall median discharge (pooling day and night) sampled was 0.55 m^3/s.

Overall, a higher proportion (0.57) of samples were collected during the day (N = 25) than at night (N = 19). However, significantly more larval fish were collected at night than during the day (Wilcoxon/Kruskal Wallis, Median test, and Van der Waerden; density Figure 3, all p values < 0.0001; abundance Figure 4, all p values < 0.0002). A total of 1,286 (96.8%) larval fish were collected at night, while only 42 (3.2%) larval fish were collected during the day.

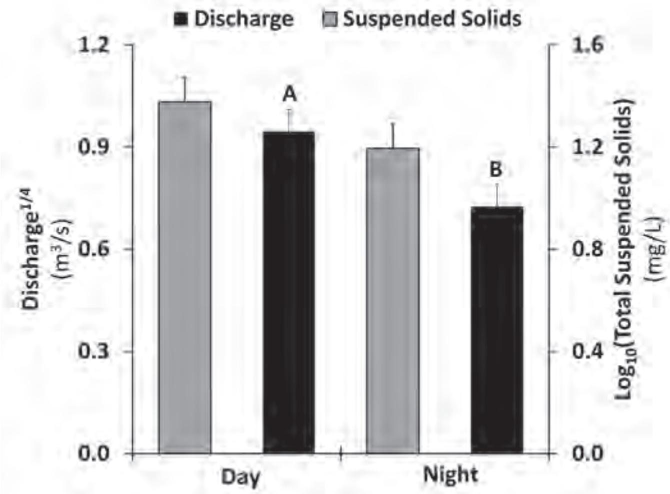

FIGURE 2. Night and day comparisons in the transformed concentrations of total suspended solids and stream discharge during each larval fish collection. Stream discharge was significantly higher during day collections (ANOVA; $F_{1,42} = 5.67$, $p = 0.0219$; indicated by non-like letters).

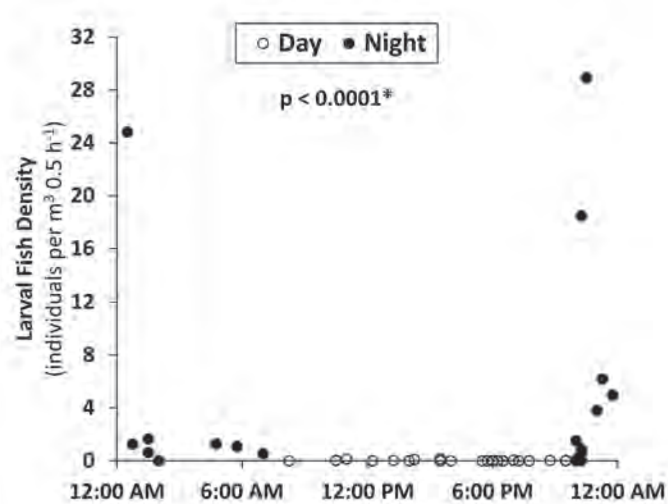

FIGURE 3. Density of larval fish collected in Honey Creek. Filled circles (•) were collected at night, while open circles (○) were collected during the day. Significantly more larval fish were collected at night (Wilcoxon/Kruskal Wallis, Median test, and Van der Waerden; all p values < 0.0001).

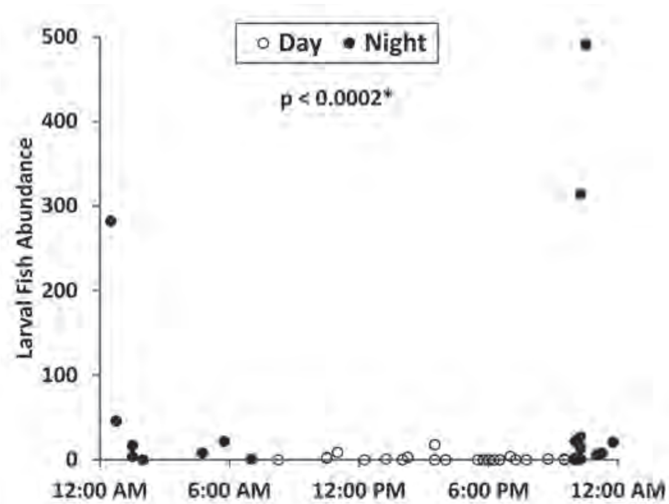

FIGURE 4. Abundance of larval fish collected in Honey Creek. Filled circles (•) were collected at night, while open circles (○) were collected during the day. Significantly more larval fish were collected at night (Wilcoxon/Kruskal Wallis, Median test, and Van der Waerden; all p values < 0.0002).

DISCUSSION

While diel drift had been previously observed in a small stream with limited temporal replication (3 d period) by Johnson and McKenna (2007), we observed diel drift over extensive temporal sampling. A total of 44 larval fish samples were collected over a 124 d period, thus averaging a sample every 2.8 d. Furthermore, this is the first larval fish study that we know of in a small stream to observe both a diel drifting pattern and to investigate correlations between day and night larval fish densities with turbidity and stream discharge.

Catostomids comprised the majority (80%) of the larval fish drifting in Honey Creek. However, high proportions of drifting catostomids have been observed in other systems. For example, the flannelmouth sucker *(Catostomus latipinnis)*, bluehead sucker *(Catostomus discobolus)*, and white sucker *(Catostomus commersonii)* comprised 65-75% of the total catch in the upper Colorado River (Carter and others 1986). Additionally, catostomids represented 58% of the total larval fish community in Luxapallila Creek, Mississippi (Raborn and others 2001).

Percids showed a similar temporal drift pattern to catostomids (Table 1). Drifting percids included logperch *(Percina caprodes)* and other species of darters. Cyprinids were present from the middle of May to August, with blacknose dace *(Rhinichthys atratulus)* appearing first, followed by bluntnose minnows *(Pimephales notatus)* and spotfin shiners *(Cyprinella spiloptera)*. Channel catfish *(Ictalurus punctatus)* were present at the end of June and the beginning of July, while stonecat madtoms *(Noturus flavus)* did not appear in the drift until the beginning of August. Centrarchids were present in the drift from middle of May (smallmouth bass; *Micropterus dolomieui*) to August at consistently low densities. Although some fish disperse randomly throughout the water column, others (e.g., centrarchids) may be more likely to occur in backwater areas rather than drifting in the channel (Gadomski and Barfoot 1998). Overall, the order of appearance and succession of the larval fish community in Honey Creek is similar to that observed by Floyd and others (1984) in the Middle Fork of Drake's Creek, Kentucky.

Most of the larval fish were collected at night, with 96.8% caught between 22:00-7:00. The results support the majority of literature that found significantly more larval fish drifting at night (Clark and Pearson 1980, Carter and others 1986, Gadomski and Barfoot 1998, White and Harvey 2003), but a minority of studies have found significantly more larval fish drifting during the day (see summary in Reeves and Galat 2010). In Honey Creek, no correlation was found between larval fish density and stream discharge or total suspended solids concentration. Thus, larval fish densities are higher at night regardless of stream flow and turbidity, supporting the theory that drift is an active behavior driven by light intensity (Reichard and others 2002). The high proportion of yolk-sac larvae (0.40) and larvae (0.56) collected in Honey Creek also suggests that even small, early developmental stages of larval fish can avoid drifting (Kennedy and Vinyard 1997). However, the relationship between time of day and drifting larval fish may not be evident during severe floods (Harvey 1987) or in deep river systems with high, chronic turbidity levels (Reeves and Galat 2010).

The water quality of the Sandusky River watershed has been studied in great detail (Richards and others 2001, Grunwald and Qi 2006), along with its adult fish community (Yoder and Beaumier 1986). Less is known about the dynamics of the larval fish community in the Sandusky River, especially in the upper portion of the watershed. Mion and others (1998) collected larval walleye *(Sander vitreus)* in the lower 25 km of the Sandusky River and found a correlation between stream discharge and walleye recruitment. However, they assumed that larval fish drift was a passive behavior, rather than the active behavior observed in this study. Subsequently, Gillenwater and others (2006) found that successful reproduction of walleye in the lower Sandusky River could be limited by the reduction of suitable spawning habitat during high stream discharge. Even larval fish in early developmental stages exhibited a diel drifting pattern in Honey Creek. Because of this, future larval fish studies in the Sandusky River and elsewhere should consider increasing the frequency of temporal sampling.

This study determined that larval fish exhibit diel drift in a small stream, suggesting drift plays an important role in the life-history of fish communities in small streams. Aquatic systems such as streams exemplify the importance of connectivity (e.g., upstream-downstream) and understanding linkages between ecosystems (Lamberti and others 2010). Similar to the stream colonization concept found in aquatic macroinvertebrates (Müller 1974, Müller 1982), fish exhibit upstream spawning migrations, counteracting larval drift with annual recolonization of headwaters (Schlosser 1987, Schlosser 1991). Although the physical limitations of larval fish movement are known (Osse and van den Boogaart 2000, Müller and others 2008), even under different water viscosities due to changes in temperature (Hunt von Herbing 2002), more research is needed to understand the mechanisms that allow larval fish to avoid being carried away by the daytime currents and to recognize and respond to nocturnal currents in streams.

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